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AIR BLAST RESULTING FROM THE DETONATION
OF SMALL TNT CHARGES

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AIR BLAST RESULTING FROM THE DETONATION
OF SMALL TNT CHARGES

By

E. M. Fisher
J. F. Pittman

Approved by: J. F. Moulton, Jr.
Acting Chief,
Explosion Effects Division

↓
ABSTRACT: Centrally boosting one pound cast TNT spheres resulted in obtaining air blast peak pressures about 15 per cent below the accepted values. Placing the booster half in and half out of the surface of a one pound cast TNT sphere resulted in a detonation that produced the accepted peak air blast pressures. A larger 7.9 pound spherical cast TNT charge was fired to show that the accepted values of blast could be obtained by central initiation providing the charge was large enough.

It was noted that the secondary shock was in a decidedly different location for a poor detonating charge as compared to charges yielding the accepted values of peak pressure.

The effect of poor detonation on impulse was about half as much as it was for peak pressure.

Explosives Research Department
U.S. NAVAL ORDNANCE LABORATORY
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The work described in this report was done in order to demonstrate the difficulty of detonating small charges of TNT and to warn those using small charge TNT data of the possible pitfalls of poor detonation. This work describes a number of ways of recognizing poor detonation in TNT and a successful way for boosting a one-pound spherical TNT charge. This work was performed under Task NOL-Re2c-2-1-53.

The authors wish to acknowledge the work of the investigation group who aided in the field and data reduction work:

J. D. Rowe
R. Robertson
E. Murray
M. J. Bengston
R. Huff

EDWARD L. WOODYARD
Captain, USN
Commander


PAUL M. FYE
By direction

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AIR BLAST RESULTING FROM THE DETONATION OF SMALL TNT CHARGES

INTRODUCTION

1. Experimental work has in the past indicated that TNT is a fairly troublesome explosive to detonate high order. Unpublished work recalled by people from the Underwater Explosive Research Laboratory, UERL, indicates that cylindrical TNT charges in small weights (under one pound) very often detonated poorly both in air and underwater. Unpublished experimental work at UERL further indicated that the best way to detonate a cylindrical charge is to use a booster located half in and half out of one of the ends as contrasted with a booster centrally located or a booster completely outside the charge on one end.
2. The experience of the air blast group at the Naval Ordnance Laboratory in the recent past has indicated that a one pound spherical charge of TNT centrally detonated by a 45 gram spherical pentolite booster gave a peak pressure blast effect that would be expected by three-fourths of a pound of TNT and a positive impulse blast effect of nine-tenths of a pound of TNT. Poor detonation was suspected as the cause of this effect. This report will discuss the experiment designed to determine whether poor detonation was the cause of this effect and if so how to detonate properly one pound of spherically cast TNT. This experiment will also show that the scaling laws for peak pressure for one and eight pounds of TNT apply when detonation is proper.

DESIGN OF EXPERIMENT

3. Six 7.9 pound charges of cast spherical TNT centrally initiated with a 0.5 pound spherical pentolite booster were fired as the control shots since it was known that these charges detonate properly (reference (a)). Six one pound spherical charges of cast TNT centrally initiated with a 45 gram spherical pentolite booster were fired in order to repeat the poor performance of these charges that was previously observed. Six one pound spherical cast TNT charges were fired in which the 45 gram spherical pentolite booster was located half in and half out of the surface of the sphere of TNT. This was an attempt to get successful detonation of a sphere by techniques described for cylinders. When mounted for firing, these charges

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were oriented with the booster vertically above the charge center.

4. All of the above charges were fired with an Engineer Special detonator. Charges and gages were placed on a horizontal plane 12 feet in the air. A plan view of the set-up is shown in Fig. 1. Measurements of peak pressure were made by the velocity method (reference (b)), using the two-cap method for wind and sound velocity measurements. Pressure-time measurements were made by tourmaline piezo-electric gages using conventional techniques, (reference (c)). Briefly these techniques involve the use of cables leading the tourmaline piezo-electric gage signals back to the recording system. The recording system amplifies these signals and impresses them on the deflection plates of a cathode ray tube. The resulting deflection of the cathode ray spot is photographed as a function of time by a rotating drum camera.

ANALYSIS OF THE DATA

5. Peak pressure was calculated by the application of the peak pressure-shock velocity relation derived from the Rankine-Hugoniot equations, references (b) and (c). Positive impulse was calculated by integrating under the positive phase of the pressure-time curve including that portion of the secondary shock, Fig. 5, that is in the positive phase. The pressure scale for the pressure-time records was determined from the pressure as measured by the velocity method for the particular shot and distance rather than by a gage calibration. Allowance was made for the effect of finite gage size in reducing the apparent peak height in the pressure-time records.

6. In Fig. 2 graphs of peak pressure versus reduced distance show clearly the poor results obtained by central initiation of one pound bare spherical charges of cast TNT in comparison to similar charges detonated with boosters half in and half out of the spherical surface. Fig. 2 shows also that central initiation for the 7.9 pound sphere of TNT produces air blast peak pressures that scale to those obtained for the surface initiation of the one pound spheres and also that the slope of the pressure distance curves for surface initiation of the spherical charge is essentially the same as for central initiation. These results are in agreement with previous 7.9 pound results, reference (a), which are in turn the accepted values at sea level for TNT when detonation is considered high order.

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7. Table I is a compilation of the experimental peak pressure results and Table II is a compilation of the experimental positive impulse values obtained from all shots in these tests.

8. The table below expresses the results of these experiments in terms of the ratio of the weight of TNT detonating in the accepted manner to the weight of TNT in the test charge that will produce the same blast effect at the same distance.

Charge Description	:Peak Pres- :sure Results	:Positive Im- :pulse Results
7.9 pound Spherical Cast TNT with central 0.5 lb spheri- cal pentolite booster	: : : : 1.00	: : : : -
One pound Spherical Cast TNT with 45 gram spherical pento- lite booster embedded half in: and half out of spherical surface	: : : : 1.01 \pm .03* :	: : : : 1.00 :
One pound Spherical Cast TNT with central 45 gram spheri- cal pentolite booster	: : : : 0.81 \pm .02 :	: : : : 0.91 :

*Standard error.

9. Examination of the pressure-time records, Fig. 5, reveals an interesting effect on the secondary shock. For the two types of charges producing the accepted blast parameters for TNT the secondary shock stayed close to the atmospheric pressure level. For the charge producing blast less than the accepted TNT values the secondary shock occurred decidedly earlier in time with respect to the primary shock. Fig. 4 shows graphically the time difference between primary and secondary shock as a function of distance for the two kinds of one pound TNT charges fired.

CONCLUSIONS

10. TNT can give erroneous air blast results when initiation is not proper. These erroneous results can

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be obtained as consistently as the accepted results. In these experiments central initiation of one pound of TNT produced peak pressures about 15 per cent lower than surface initiation of the same one pound spheres of TNT.

11. The location of the secondary shock on the time base relative to the primary shock may yield information as to the quality of the detonation. Proper detonation in TNT in these experiments placed the secondary shock furthest away in time from the primary shock, see Fig. 5. The slope of the pressure-distance curve for the surface initiation of the spherical charge compared to the centrally initiated charge, appears to be the same in the region measured.

12. The effect of the poor detonation on positive impulse was about half as much as it was for peak pressure.

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TABLE I

PEAK PRESSURE RESULTS

1# Cast TNT Sphere with Booster Centrally Located

SHOT	d	5.70	6.70	7.70	8.95	10.70	12.95	16.20	20.70
	r	5.71	6.71	7.71	8.96	10.71	12.96	16.22	20.72
1		17.09	11.35	10.67	7.34	5.46	4.12	2.74	1.49
3		18.58	14.25	10.66	8.89	6.07	3.80	2.62	1.80
4		17.63	14.43	10.15	8.14	5.13	3.87	2.39	1.39
6		19.17	13.92	10.36	7.85	6.20	4.36	3.27	2.18
9		18.42	12.65	11.09	7.99	6.07	4.29	3.18	2.37
11		17.86	12.10	10.06	6.65	4.95	3.45	2.32	1.47
13		18.22	11.96	10.45	6.79	5.28	3.67	2.53	1.53
Mean		18.14	12.95	10.49	7.66	5.59	3.94	2.72	1.75
σ		3.8%	9.6%	3.4%	10.4%	9.1%	8.5%	13.6%	22.0%
σ_p		1.4%	3.6%	1.3%	3.9%	3.5%	3.2%	5.1%	8.3%

$$P = -.637 + \frac{33.546}{r} + \frac{286.411}{r^2} + \frac{755.234}{r^3}$$

1# Cast TNT Spheres with Booster half in and half out of Spherical Surface

SHOT	d	5.70	6.70	7.70	8.95	10.70	12.95	16.20	20.70
	r	5.64	6.63	7.62	8.66	10.59	12.82	16.04	20.49
2		22.40	15.65	12.37	9.55	6.40	5.05	3.46	2.22
5		21.59	15.81	13.59	9.50	6.73	4.79	3.21	1.90
7		22.95	15.80	12.47	8.90	6.62	4.96	3.26	2.39
8		22.18	15.45	11.82	8.32	6.28	4.57	2.92	2.09
10		20.23	12.86	11.44	8.40	5.66	3.92	2.62	1.58
12		19.33	14.89	12.60	8.51	6.59	4.88	3.34	2.44
14		22.48	15.34	13.01	8.27	6.43	4.77	3.50	2.54
Mean		21.59	15.49	12.47	8.78	6.51	4.84	3.28	2.17
σ		6.1%	2.3%	5.7%	6.2%	2.5%	3.5%	6.4%	15.7%
σ_p		2.3%	0.9%	2.2%	2.4%	1.0%	1.4%	2.6%	5.9%

$$P = .086 + \frac{19.242}{r} + \frac{467.028}{r^2} + \frac{607.691}{r^3}$$

.9# Spherical Cast TNT with Centrally Located Booster

SHOT	d	7.70	8.95	10.70	12.95	16.20	20.70
	r	7.67	8.50	9.38	10.51	13.14	16.41
15		54.74	36.88	23.24	16.51	10.32	6.57
16		51.86	36.50	24.92	16.65	10.38	6.54
17		50.55	35.11	22.50	15.95	10.14	6.25
18			35.73	26.10	16.38	10.12	6.54
19			39.50	24.48	17.12		
20			36.48	23.98	15.81	10.18	6.34
Mean		52.39	36.14	24.20	16.40	10.23	6.45
σ		4.1%	2.0%	5.2%	2.9%	1.2%	2.2%
σ_p		2.4%	0.9%	2.1%	1.2%	0.5%	1.0%

$$P = -6.539 + \frac{152.834}{r} - \frac{559.978}{r^2} - \frac{3204.774}{r^3}$$

* Datum disregarded in accordance with Chauvenet's Criterion.

d = distance from charge in feet

r = reduced distance $d/W^{1/3}$, $\left(\frac{\text{ft}}{\text{lb}}\right)^{1/3}$

Pressures are in psi

σ = standard deviation

σ_p = standard error.

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TABLE II
POSITIVE IMPULSE RESULTS

10 Cast TNT Spheres with Booster Centrally Located

SHOT	d	8.95	10.70	12.92
	7.70	8.95	10.70	12.92
1	6.93 6.57	5.70	5.39 4.87	4.10 4.08
3	8.69 7.36	7.12 5.93	5.24 4.80	3.90 4.22
4	7.72 7.85	6.74 5.59	4.79 4.06	3.29 3.39
6	7.00 6.87	6.72 6.30	5.97 5.06	4.51 4.59
9	7.82 6.74	6.35 6.26	6.31 5.41	4.38 4.59
11	8.12 6.34	6.50 5.17	4.14 3.91	3.57 3.70
13	7.39 6.87	5.72 5.18	4.81 4.02	3.83 3.76
Mean	7.26	6.10	4.91	3.99
$1/\sqrt{1/3}$	7.27	6.11	4.91	3.99
$\% \sigma_I$	9.8%	10.0%	14.9%	10.8%
$\% \sigma_I$	2.6%	2.8%	4.1%	2.6%

10 Cast TNT Spheres with Booster
Half in and Half out of Spherical Surface

SHOT	d	8.95	10.70	12.92
	7.70	8.95	10.70	12.92
2	7.32	6.47	5.77 5.32	4.62
5	7.90 8.10	7.21 7.10	6.15 5.53	4.59 4.57
7	7.72 7.35	6.92 6.42	6.01 5.58	4.40 4.73
8	7.04 6.98	6.99 5.40	5.41 4.81	4.02 4.17
10	7.62 6.66	6.13 5.59	4.69 4.59	
12	8.74 8.23	7.04 6.49	6.16 5.20	4.39 4.19
14	9.42 7.25	7.41 7.02	5.47 5.31	4.06
Mean	7.58	6.63	5.42	4.40
$1/\sqrt{1/3}$	7.50	6.56	5.37	4.36
$\% \sigma_I$	7.8%	9.4%	9.2%	5.6%
$\% \sigma_I$	2.1%	2.6%	2.4%	1.8%

7.9% Spherical Cast TNT with Centrally Located Booster

SHOT	d	8.95	10.70	12.92
	7.70	8.95	10.70	12.92
15	35.52 27.67	24.94 19.18	17.67	13.35 17.77
16	24.60 25.33	21.97 20.00	19.66 18.02	13.59 17.65
17	26.36 20.60	23.48 18.88	15.83	13.61 16.51
18		24.34 16.61	17.36 18.37	15.05 17.87
19			19.15 17.73	17.92 18.49
20	30.54 22.14	21.52 22.02	17.31 21.71	15.33 16.41
Mean	26.65	21.18	17.90	16.22
$1/\sqrt{1/3}$	12.73	10.65	9.00	8.16
$\% \sigma_I$	13.2%	7.9%	5.1%	11.5%
$\% \sigma_I$	3.0%	3.4%	2.0%	3.3%

* Data disregarded in accordance with Chauvenet's Criterion.

d = distance from charge in feet
r = reduced distance $d/\sqrt{1/3}$ (ft.^{1/3})

Positive impulse is in pos-
cm.

$1/\sqrt{1/3}$ = reduced positive impulse

σ_I = standard deviation

σ_I = standard error.

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- b. P. Z. Kalavski, A High Speed Recording System Using the Velocity Method to Determine the Peak Pressure in Air by Explosives, NAVORD Report 2167, Unclassified, Feb 1952.
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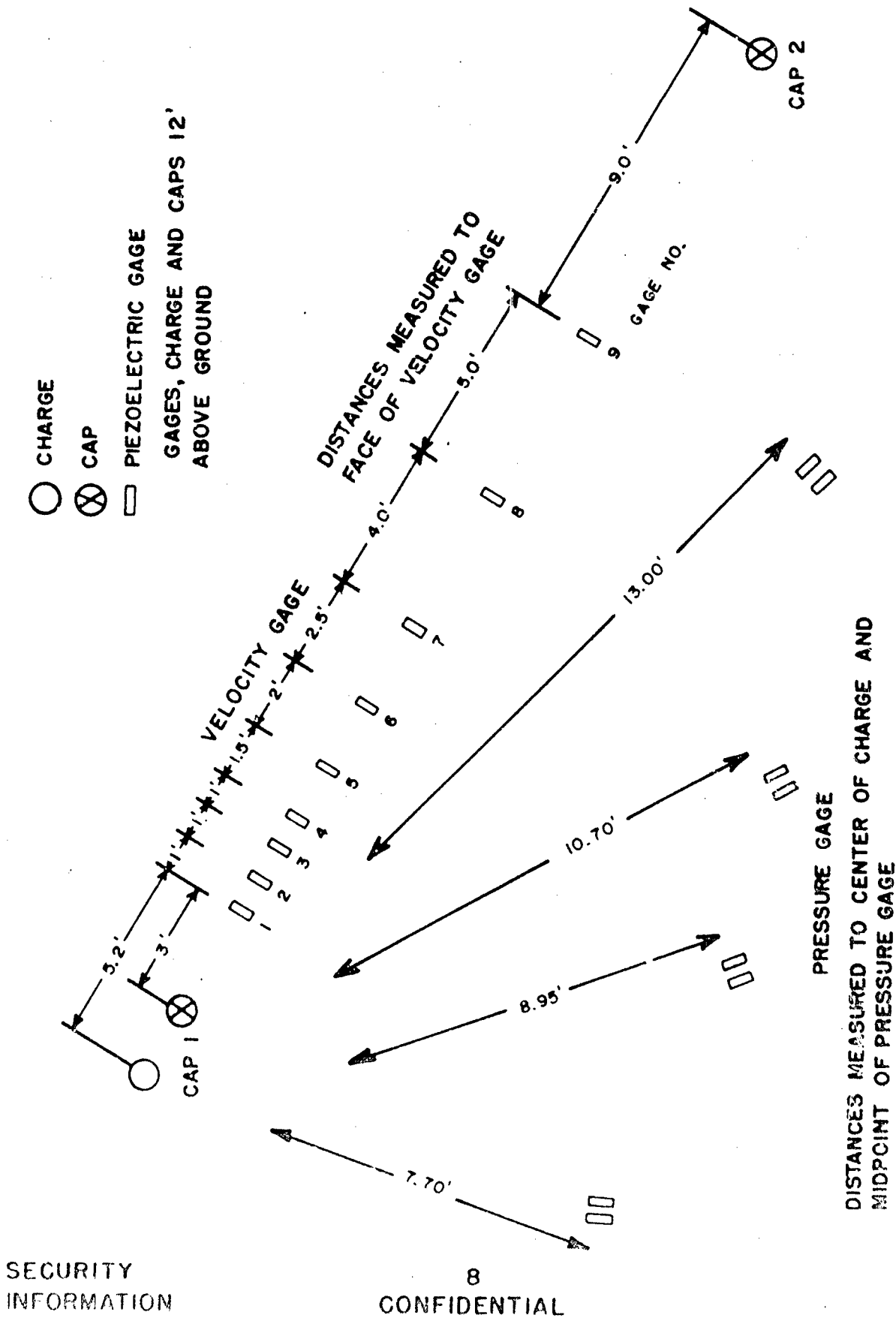


FIG. 1 PLAN OF GAGE AND CHARGE LAYOUT

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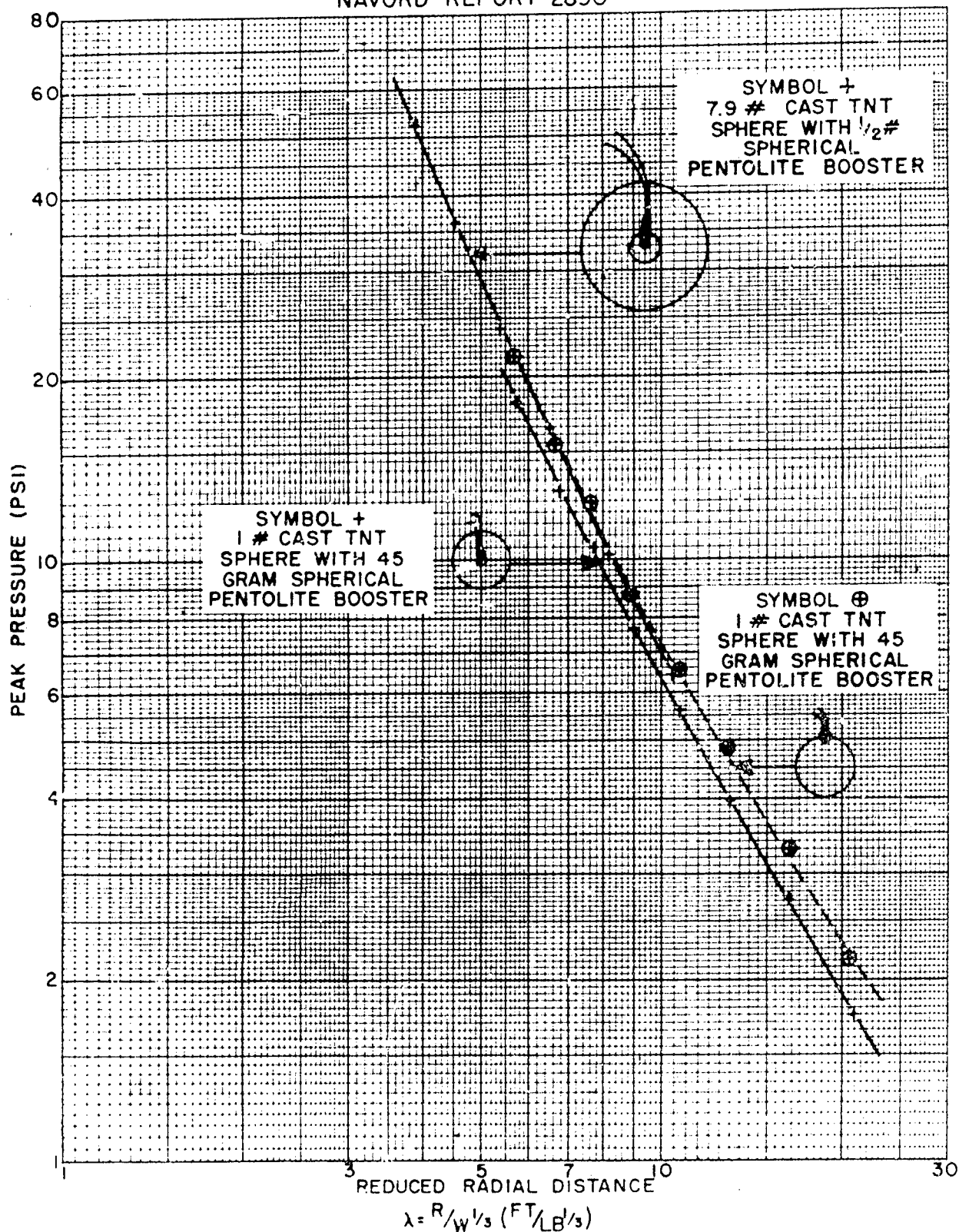


FIG. 2 PEAK PRESSURE VS REDUCED DISTANCE

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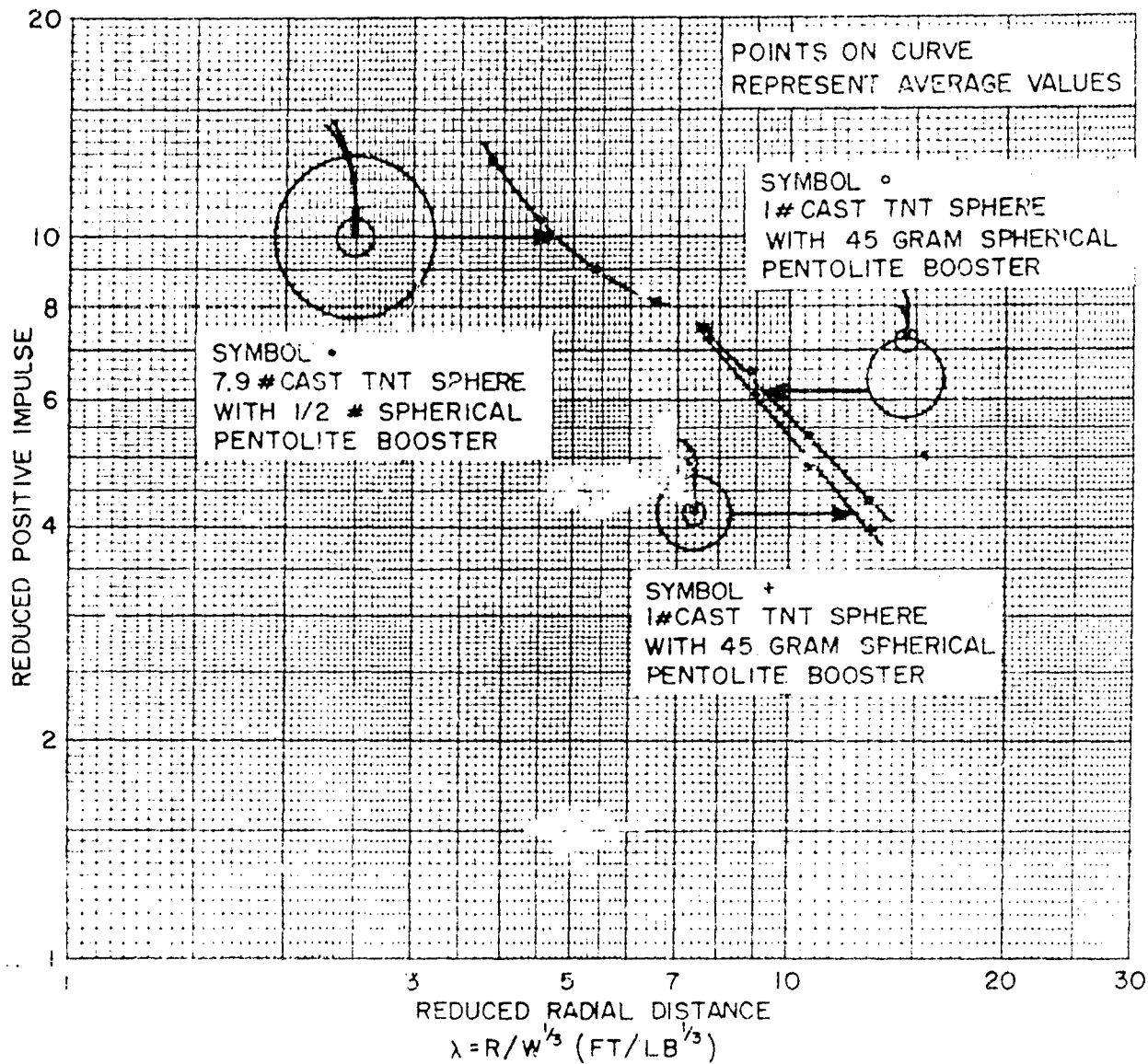


FIG. 3 REDUCED POSITIVE IMPULSE VS REDUCED DISTANCE

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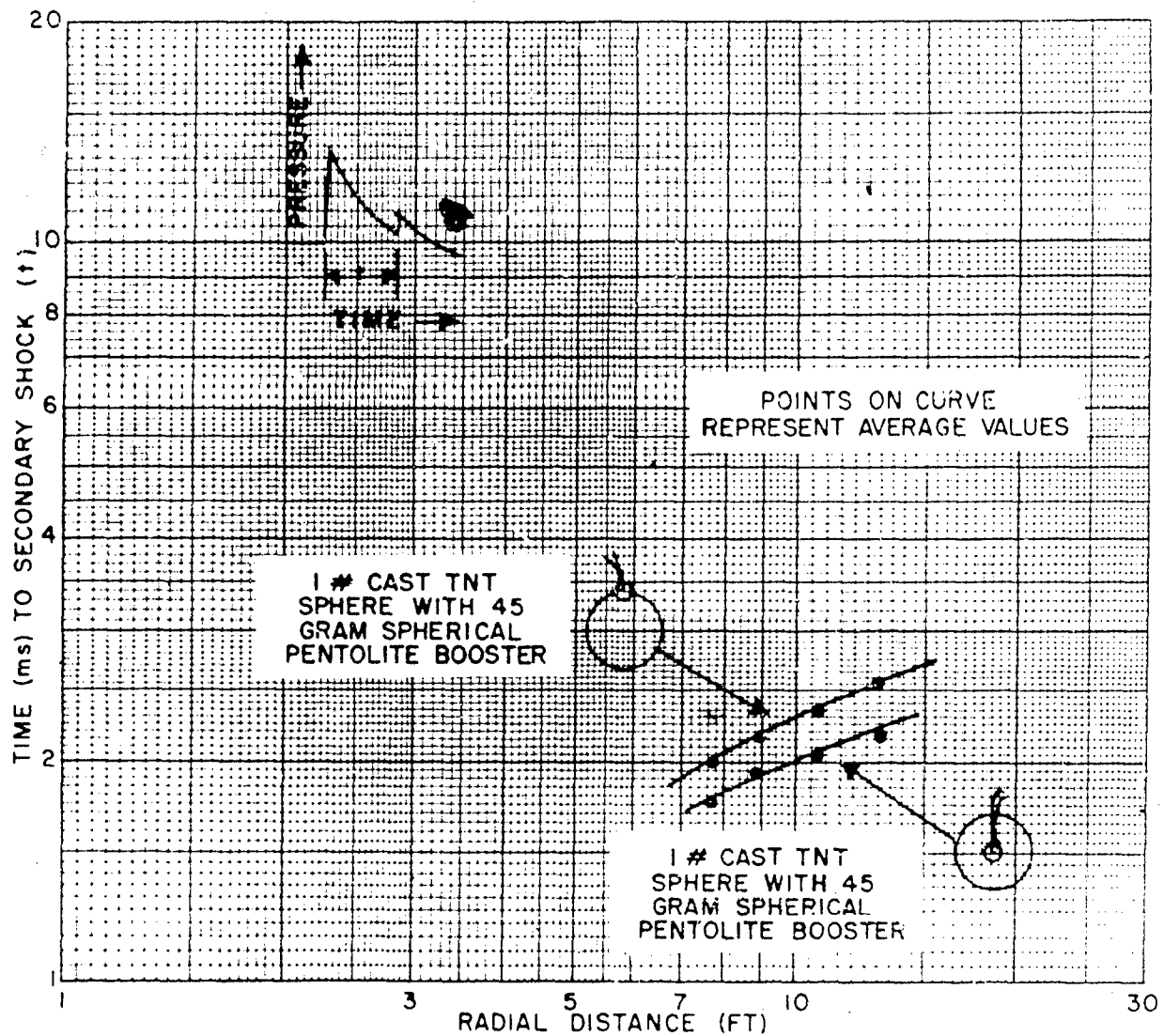
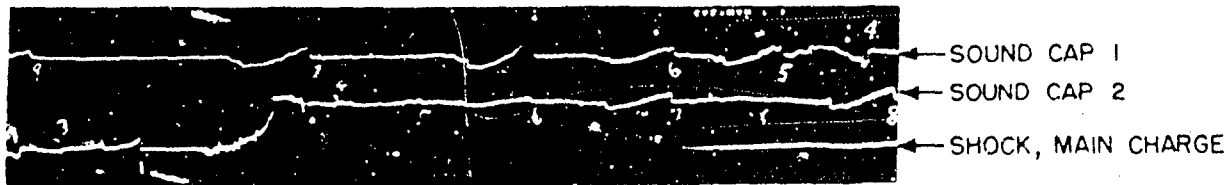


FIG. 4 TIME TO SECONDARY SHOCK VS GAGE TO CHARGE DISTANCE

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A PORTION OF A VELOCITY RECORD



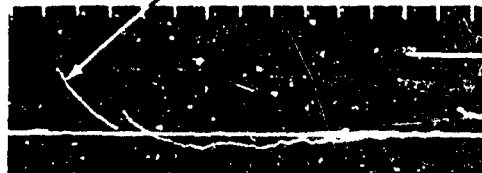
ARROWS SHOW PIPS PRODUCED BY GAGES ON ARRIVAL OF SOUND AND SHOCK WAVES. NUMBERS CORRESPOND TO VELOCITY GAGE NUMBERS OF FIG. 1, THIS REPORT

PRESSURE TIME RECORDS

1 LB CAST TNT SPHERE WITH
45 GRAM SPHERICAL PENTOLITE
BOOSTER LOCATED HALF
IN AND HALF OUT OF SPHERICAL
SURFACE



1 LB CAST TNT SPHERE WITH
45 GRAM SPHERICAL PENTOLITE
BOOSTER CENTRALLY LOCATED



PRIMARY SHOCK
SECONDARY SHOCK
GROUND REFLECTION

THE ABOVE TWO RECORDS TAKEN AT THE SAME DISTANCE FROM THE
TWO TYPES OF 1 LB CHARGES SHOW CLEARLY THE DIFFERENT LOCA-
TIONS OF SECONDARY SHOCK

7.9 LB CAST TNT SPHERE WITH
1/2 LB SPHERICAL PENTOLITE
BOOSTER



NOTE: ALL TIMING MARKS
ARE AT 1 MILLISECOND
INTERVALS

FIG. 5

TYPICAL RECORDS

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